

## WHAT IS CLAIMED IS:

1. A collimating plate comprising:

a lens substrate;

a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas, each having a circular form a center of which is on an optical axis of each of said plurality of microlenses and set on another surface of the lens substrate reverse to said plurality of microlenses; and

a light shield layer formed on another surface of said lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein when a refractive index of said lens substrate is represented by  $n$ ; a thickness of said lens substrate by  $t$ ; a diameter of each of said plurality of light entrance areas by  $R$ ; and a size of each of said plurality of microlenses by  $S_r$ , the following formula (1):

$$S_r \geq 2t \times \tan\theta + R \quad (1)$$

(with the proviso that  $\theta = \sin^{-1}(1/n)$ )

is satisfied.

2. The collimating plate according to claim 1, further comprising a diffuse reflecting layer formed at a light entrance

side than said light shield layer so as to cover other area than said plurality of light entrance areas.

3. The collimating plate according to claim 1, wherein said plurality of microlenses are either in circular form when viewed from a direction of the optical axis and are arranged in a closest packing state or in hexagonal form when viewed from the direction of the optical axis and are arranged in a hexagonal close-packed state.

4. The collimating plate according to claim 1, wherein said refractive index of said lens substrate is between 1.4 and 2.

5. A lighting apparatus comprising:

a light source;

a lamp housing for containing said light source, whose inner surfaces are covered with a diffuse reflecting layer; and

a collimating plate,

wherein said collimating plate comprises a lens substrate;

a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas, each having a circular form a center of which is on an optical axis of each of said

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plurality of microlenses and set on another surface of the lens substrate reverse to said plurality of microlenses; and

a light-shield layer formed on another surface of said lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein when a refractive index of said lens substrate is represented by  $n$ ; a thickness of said lens substrate by  $t$ ; a diameter of each of said plurality of light entrance areas by  $R$ ; and a size of each of said plurality of microlenses by  $S_r$ , the following formula (1):

$$S_r \geq 2t \times \tan\theta + R \quad (1)$$

(with the proviso that  $\theta = \sin^{-1}(1/n)$ )

is satisfied.

6. A lighting apparatus comprising:

a collimating plate; and

a plurality of light sources,

wherein said collimating plate comprises a lens substrate;

a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas, each having a circular form a center of which is on an optical axis of each of said plurality of microlenses and set on another surface of the lens substrate reverse to said plurality of microlenses; and

a light shield layer formed on another surface of said lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein when a refractive index of said lens substrate is represented by  $n$ ; a thickness of said lens substrate by  $t$ ; a diameter of each of said plurality of light entrance areas by  $R$ ; and a size of each of said plurality of microlenses by  $S_r$ , the following formula (1):

$$S_r \geq 2t \times \tan\theta + R \quad (1)$$

(with the proviso that  $\theta = \sin^{-1}(1/n)$ )

is satisfied, and

wherein said plurality of light sources are disposed in said plurality of light entrance areas of said collimating plate respectively.

7. The lighting apparatus according to claim 6, wherein a light emission size of each of said plurality of light sources is smaller than a size of each of said plurality of light entrance areas.

8. The lighting apparatus according to claim 6, wherein said plurality of light sources are LEDs or organic EL devices.

9. A liquid crystal display apparatus comprising:

a liquid crystal display panel; and

a lighting apparatus for launching light into said liquid crystal display panel,

wherein said lighting apparatus comprises a light source;

a lamp housing for containing said light source, whose inner surfaces are covered with a diffuse reflecting layer; and

a collimating plate,

wherein said collimating plate comprises a lens substrate;

a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas, each having a circular form a center of which is on an optical axis of each of said plurality of microlenses and set on another surface of the lens substrate reverse to said plurality of microlenses; and

a light shield layer formed on another surface of said lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein when a refractive index of said lens substrate is represented by  $n$ ; a thickness of said lens substrate by  $t$ ; a diameter of each of said plurality of light entrance areas by  $R$ ; and a size of each of said plurality of microlenses by  $S_r$ , the following formula (1):

$$S_r \geq 2t \times \tan\theta + R \quad (1)$$

(with the proviso that  $\theta = \sin^{-1}(1/n)$ )

is satisfied.

10. The liquid crystal display apparatus according to claim 9, further comprising a light diffusing plate for diffusing an image-bearing light which has passed through said liquid crystal display panel.

11. A liquid crystal display apparatus comprising:  
a liquid crystal display panel; and  
a lighting apparatus for launching light into said liquid crystal display panel,

wherein said lighting apparatus comprises a collimating plate; and

a plurality of light sources,  
wherein said collimating plate comprises a lens substrate;  
a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas, each having a circular form a center of which is on an optical axis of each of said plurality of microlenses and set on another surface of the lens substrate reverse to said plurality of microlenses; and

a light shield layer formed on another surface of said lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

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$$S_r \geq 2t \times \tan\theta + R \quad (1)$$

is satisfied, and

12. A collimating plate comprising:

a lens substrate;

a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas, each having a rectangular form a center of which is on an optical axis of each of said plurality of microlenses and set on another surface of the lens substrate reverse to said plurality of microlenses; and

a light shield layer formed on another surface of said lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein, when a refractive index of said lens substrate is represented by  $n$ ; a thickness of said lens substrate by  $t$ ; a length of a side of each of said plurality of light entrance areas by  $A$ ; a length of another side of each of said plurality of light entrance areas by  $B$ ; a size of each of said plurality of microlenses in a direction of said length  $A$  represented by  $S_a$ ; and a size of each of said plurality of microlenses in a direction of said length  $B$  represented by  $S_b$ , the following formulae (2) and (3):

$$S_a \geq 2t \times \tan\theta + A \quad (2)$$

$$S_b \geq 2t \times \tan\theta + B \quad (3)$$

(with the proviso that  $\theta = \sin^{-1}(1/n)$ )

are satisfied.

13. The collimating plate according to claim 12, wherein said plurality of microlenses are either in square form viewed from a direction of the optical axis and are arranged in a square closed-packed state or in rectangular form viewed from the direction of the optical axis and are arranged in a rectangular closed-packed state.

14. A lighting apparatus comprising:

a light source;

a lamp housing for containing said light source, whose

inner surfaces are covered with a diffuse reflecting layer; and

a collimating plate,

wherein said collimating plate comprises a lens substrate;

a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas, each having a rectangular form a center of which is on an optical axis of each of said plurality of microlenses and set on another surface of the lens substrate reverse to said plurality of microlenses; and

a light shield layer formed on another surface of said lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein, when a refractive index of said lens substrate is represented by  $n$ ; a thickness of said lens substrate by  $t$ ; a length of a side of each of said plurality of light entrance areas by  $A$ ; a length of another side of each of said plurality of light entrance areas by  $B$ ; a size of each of said plurality of microlenses in a direction of said length  $A$  represented by  $S_a$ ; and a size of each of said plurality of microlenses in a direction of said length  $B$  represented by  $S_b$ , the following formulae (2) and (3):

$$S_a \geq 2t \times \tan\theta + A \quad (2)$$

$$S_b \geq 2t \times \tan\theta + B \quad (3)$$

(with the proviso that  $\theta = \sin^{-1}(1/n)$ )

are satisfied.

15. A lighting apparatus comprising:

a collimating plate; and

a plurality of light sources,

wherein said collimating plate comprises a lens substrate;

a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas, each having a rectangular form a center of which is on an optical axis of each of said plurality of microlenses and set on another surface of the lens substrate reverse to said plurality of microlenses; and

a light shield layer formed on another surface of said lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein, when a refractive index of said lens substrate is represented by  $n$ ; a thickness of said lens substrate by  $t$ ; a length of a side of each of said plurality of light entrance areas by  $A$ ; a length of another side of each of said plurality of light entrance areas by  $B$ ; a size of each of said plurality of microlenses in a direction of said length  $A$  represented by  $S_a$ ; and a size of each of said plurality of microlenses in a

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direction of said length B represented by  $S_b$ , the following formulae (2) and (3):

$$S_a \geq 2t \times \tan\theta + A \quad (2)$$

$$S_b \geq 2t \times \tan\theta + B \quad (3)$$

(with the proviso that  $\theta = \sin^{-1}(1/n)$ )

are satisfied, and

wherein said plurality of light sources are disposed in said plurality of light entrance areas of said collimating plate respectively.

16. A liquid crystal display apparatus comprising:
  - a liquid crystal display panel; and
  - a lighting apparatus for launching light into said liquid crystal display panel,
 wherein said lighting apparatus comprises a light source;
  - a lamp housing for containing said light source, whose inner surfaces are covered with a diffuse reflecting layer; and
  - a collimating plate,
 wherein said collimating plate comprises a lens substrate;
  - a plurality of microlenses disposed on a surface of said lens substrate;
  - a plurality of light entrance areas, each having a rectangular form a center of which is on an optical axis of each of said plurality of microlenses and set on another surface of

the lens substrate reverse to said plurality of microlenses;  
and

a light shield layer formed on another surface of said lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein, when a refractive index of said lens substrate is represented by  $n$ ; a thickness of said lens substrate by  $t$ ; a length of a side of each of said plurality of light entrance areas by  $A$ ; a length of another side of each of said plurality of light entrance areas by  $B$ ; a size of each of said plurality of microlenses in a direction of said length  $A$  represented by  $S_a$ ; and a size of each of said plurality of microlenses in a direction of said length  $B$  represented by  $S_b$ , the following formulae (2) and (3):

$$S_a \geq 2t \times \tan\theta + A \quad (2)$$

$$S_b \geq 2t \times \tan\theta + B \quad (3)$$

(with the proviso that  $\theta = \sin^{-1}(1/n)$ )

are satisfied.

17. A liquid crystal display apparatus comprising:  
a liquid crystal display panel; and  
a lighting apparatus for launching light into said liquid crystal display panel,

wherein said lighting apparatus comprises a collimating

plate; and

a plurality of light sources,

wherein said collimating plate comprises a lens substrate;

a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas, each having a rectangular form a center of which is on an optical axis of each of said plurality of microlenses and set on another surface of the lens substrate reverse to said plurality of microlenses; and

a light shield layer formed on another surface of said lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein, when a refractive index of said lens substrate is represented by  $n$ ; a thickness of said lens substrate by  $t$ ; a length of a side of each of said plurality of light entrance areas by  $A$ ; a length of another side of each of said plurality of light entrance areas by  $B$ ; a size of each of said plurality of microlenses in a direction of said length  $A$  represented by  $S_a$ ; and a size of each of said plurality of microlenses in a direction of said length  $B$  represented by  $S_b$ , the following formulae (2) and (3):

$$S_a \geq 2t \times \tan\theta + A \quad (2)$$

$$S_b \geq 2t \times \tan\theta + B \quad (3)$$

(with the proviso that  $\theta = \sin^{-1}(1/n)$ )

are satisfied, and

wherein said plurality of light sources are disposed in said plurality of light entrance areas of said collimating plate respectively.

18. A collimating plate comprising:

a lens substrate;

a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas disposed on another surface of said lens substrate reverse to said plurality of microlenses, and having an optical axis of each of said plurality of microlenses; and

a light shield layer formed on said another surface of the lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein a form of each of said plurality of microlenses is a part of an ellipsoid shown in the following formula (4),

wherein an eccentricity  $e$  of said ellipsoid is shown in the following formula (5) and

wherein, in said ellipsoid, a focal point away from a side from which light is issued is on a position of each of said

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Table 1. <i>Physicochemical properties of the studied water samples</i>	
Sample	Location
1	100 m from the shore
2	200 m from the shore
3	300 m from the shore
4	400 m from the shore
5	500 m from the shore
6	600 m from the shore
7	700 m from the shore
8	800 m from the shore
9	900 m from the shore
10	1000 m from the shore
11	1100 m from the shore
12	1200 m from the shore
13	1300 m from the shore
14	1400 m from the shore
15	1500 m from the shore
16	1600 m from the shore
17	1700 m from the shore
18	1800 m from the shore
19	1900 m from the shore
20	2000 m from the shore
21	2100 m from the shore
22	2200 m from the shore
23	2300 m from the shore
24	2400 m from the shore
25	2500 m from the shore
26	2600 m from the shore
27	2700 m from the shore
28	2800 m from the shore
29	2900 m from the shore
30	3000 m from the shore
31	3100 m from the shore
32	3200 m from the shore
33	3300 m from the shore
34	3400 m from the shore
35	3500 m from the shore
36	3600 m from the shore
37	3700 m from the shore
38	3800 m from the shore
39	3900 m from the shore
40	4000 m from the shore
41	4100 m from the shore
42	4200 m from the shore
43	4300 m from the shore
44	4400 m from the shore
45	4500 m from the shore
46	4600 m from the shore
47	4700 m from the shore
48	4800 m from the shore
49	4900 m from the shore
50	5000 m from the shore
51	5100 m from the shore
52	5200 m from the shore
53	5300 m from the shore
54	5400 m from the shore
55	5500 m from the shore
56	5600 m from the shore
57	5700 m from the shore
58	5800 m from the shore
59	5900 m from the shore
60	6000 m from the shore
61	6100 m from the shore
62	6200 m from the shore
63	6300 m from the shore
64	6400 m from the shore
65	6500 m from the shore
66	6600 m from the shore
67	6700 m from the shore
68	6800 m from the shore
69	6900 m from the shore
70	7000 m from the shore
71	7100 m from the shore
72	7200 m from the shore
73	7300 m from the shore
74	7400 m from the shore
75	7500 m from the shore
76	7600 m from the shore
77	7700 m from the shore
78	7800 m from the shore
79	7900 m from the shore
80	8000 m from the shore
81	8100 m from the shore
82	8200 m from the shore
83	8300 m from the shore
84	8400 m from the shore
85	8500 m from the shore
86	8600 m from the shore
87	8700 m from the shore
88	8800 m from the shore
89	8900 m from the shore
90	9000 m from the shore
91	9100 m from the shore
92	9200 m from the shore
93	9300 m from the shore
94	9400 m from the shore
95	9500 m from the shore
96	9600 m from the shore
97	9700 m from the shore
98	9800 m from the shore
99	9900 m from the shore
100	10000 m from the shore

(4)

(5)

a plurality of light entrance areas disposed on another

a light shield layer formed on said another surface of the lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein an eccentricity  $\epsilon$  of said ellipsoid is shown in the following formula (5) and

$$x^2/a^2 + y^2/a^2 + z^2/c^2 = 1 \quad (4)$$

wherein x and y represent axes on the surface of the lens substrate; z represents the optical axis; and n represents a refractive index of a material forming said plurality of microlenses.

a collimating plate; and  
a plurality of light sources,

wherein said collimating plate comprises a lens substrate;  
 a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas disposed on another surface of said lens substrate reverse to said plurality of microlenses, and having an optical axis of each of said plurality of microlenses; and

a light shield layer formed on said another surface of the lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein a form of each of said plurality of microlenses is a part of an ellipsoid shown in the following formula (4),

wherein an eccentricity  $\epsilon$  of said ellipsoid is shown in the following formula (5) and

wherein, in said ellipsoid, a focal point away from a side from which light is issued is on a position of each of said plurality of light entrance areas:

$$x^2/a^2 + y^2/a^2 + z^2/c^2 = 1 \quad (4)$$

$$\epsilon = (c^2 - a^2)^{1/2}/c = 1/n \quad (5)$$

wherein  $x$  and  $y$  represent axes on the surface of the lens substrate;  $z$  represents the optical axis; and  $n$  represents a refractive index of a material forming said plurality of microlenses, and

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wherein said plurality of light sources are disposed in said plurality of light entrance areas of said collimating plate respectively.

22. A liquid crystal display apparatus comprising:  
 a liquid crystal display panel; and  
 a lighting apparatus for launching light into said liquid crystal display panel,

wherein said lighting apparatus comprises a light source;  
 a lamp housing for containing said light source, whose inner surfaces are covered with a diffuse reflecting layer; and  
 a collimating plate,

wherein said collimating plate comprises a lens substrate;  
 a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas disposed on another surface of said lens substrate reverse to said plurality of microlenses, and having an optical axis of each of said plurality of microlenses; and

a light shield layer formed on said another surface of the lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein a form of each of said plurality of microlenses

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is a part of an ellipsoid shown in the following formula (4),

wherein an eccentricity  $\varepsilon$  of said ellipsoid is shown in the following formula (5) and

wherein, in said ellipsoid, a focal point away from a side from which light is issued is on a position of each of said plurality of light entrance areas:

$$x^2/a^2 + y^2/a^2 + z^2/c^2 = 1 \quad (4)$$

$$\varepsilon = (c^2 - a^2)^{1/2}/c = 1/n \quad (5)$$

wherein  $x$  and  $y$  represent axes on the surface of the lens substrate;  $z$  represents the optical axis; and  $n$  represents a refractive index of a material forming said plurality of microlenses.

23. A liquid crystal display apparatus comprising:  
a liquid crystal display panel; and  
a lighting apparatus for launching light into said liquid crystal display panel,

wherein said lighting apparatus comprises a collimating plate; and

a plurality of light sources,  
wherein said collimating plate comprises a lens substrate;  
a plurality of microlenses disposed on a surface of said lens substrate;

a plurality of light entrance areas disposed on another

surface of said lens substrate reverse to said plurality of microlenses, and having an optical axis of each of said plurality of microlenses; and

a light shield layer formed on said another surface of the lens substrate reverse to said plurality of microlenses so as to cover other area than said plurality of light entrance areas,

wherein a form of each of said plurality of microlenses is a part of an ellipsoid shown in the following formula (4),

wherein an eccentricity  $\epsilon$  of said ellipsoid is shown in the following formula (5) and

wherein, in said ellipsoid, a focal point away from a side from which light is issued is on a position of each of said plurality of light entrance areas:

$$x^2/a^2 + y^2/a^2 + z^2/c^2 = 1 \quad (4)$$

$$\epsilon = (c^2 - a^2)^{1/2}/c = 1/n \quad (5)$$

wherein  $x$  and  $y$  represent axes on the surface of the lens substrate;  $z$  represents the optical axis; and  $n$  represents a refractive index of a material forming said plurality of microlenses, and

wherein said plurality of light sources are disposed in said plurality of light entrance areas of said collimating plate which are surrounded with said light shield layer and said diffuse reflecting layer.

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